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EXPERIMENTAL DATA FORMING THE BASIS FOR
THE BOMBING TABLES BT-1000-B-1 FOR
THE BOMB, A.P., 1000-LB., M52

by

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U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

Ballistic Research
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Aberdeen Proving Ground, Md.
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EXPERIMENTAL DATA FORMING THE BASIS FOR THE BOMBING TABLES
BT-1000-B-1
FOR THE
BOMB, A.P., 1000-LB., M52

Abstract

This report records the essential data on which the bombing tables, BT-1000-B-1, are based. A short description of the bomb is given as well as the mechanical constants of the bombs used. The methods used in range bombing and the methods of obtaining essential data are described. Also given are the methods used to determine the ballistic coefficients, as well as the methods used in constructing the bombing tables. Graphs showing the results of range bombing and graphs showing the fitted $C : Y$ relations are included.

I. Purpose of Report

The purpose of this report is to record the essential details of the experimental work, the computing methods and the experimental data upon which the bombing tables, BT-1000-B-1, for the Bomb, A.P., 1000-lb., M52 are based.

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II. Description of Bombs

The Bombs, A.P., 1000-lb., M52 used in range bombing for the bombing tables, BT-1000-B-1, were made in accordance with Picatinny Arsenal Drawing Number 26454, dated February 6, 1941. The present Ordnance Drawing Number is 82-O-58, dated September 15, 1941.

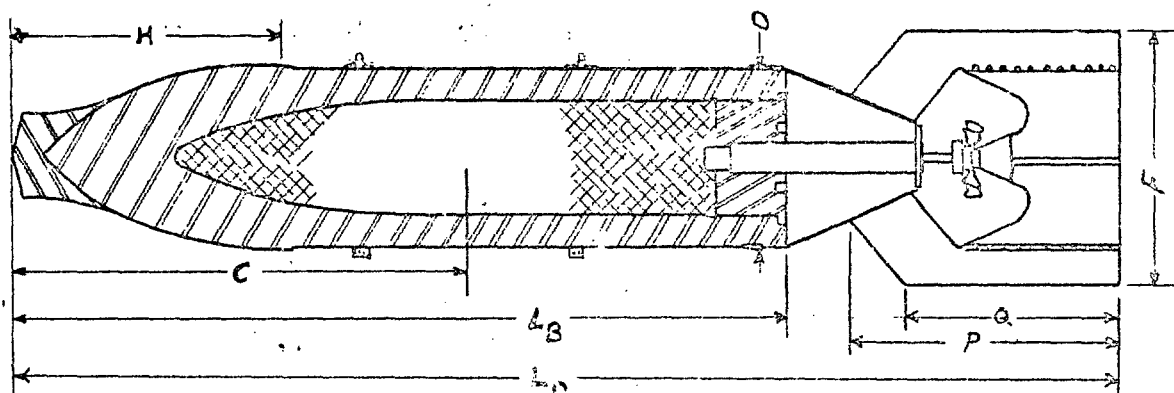
This armor-piercing bomb was made by converting the 12" Deck Piercing Shell, M1898 (Ordnance Drawing Number 75-12-4D). The shells have been converted into bombs by adding lugs to the body and by adding a fin assembly to the tail of the shell. The base plug has been altered so that the fuze hole is smaller and a smaller adapter is used. The rotating bands have been machined so that they have the same diameter as the bomb body. One half of the bombs dropped in this range bombing program were modified and half were unmodified. The unmodified bombs were equipped with

PHYSICAL CHARACTERISTICS

BOMB, A.P., 1000-LB., M52

DRG. NO. 82-0-58

REV. 9-15-41



PRINCIPAL DIMENSIONS

DIMENSION	INCHES	CALIBERS	REMARKS
D	12.25	1.00	AS GIVEN ON DRAWING
B	11.25	.91	AS GIVEN ON DRAWING
F	15.5	1.35	AS GIVEN ON DRAWING
L ₀	70.88	5.79	AS GIVEN ON DRAWING
L ₂	40.53	4.04	AS GIVEN ON DRAWING
H	18.1	1.31	AS GIVEN ON DRAWING
P	17.5	1.44	AS GIVEN ON DRAWING
Q	14.4	1.18	AS GIVEN ON DRAWING
C	28.32 ± 0.153	2.31	AS GIVEN ON DRAWING
C			CHARGE ASSEMBLY, INCLUDING FUZE AND LOCK NUT, AS GIVEN ON DRAWING

COMPONENTS AND WEIGHTS

COMPONENTS		WEIGHT	REMARKS
BODY ASSEMBLY	BODY	983.	INCLUDING SUBSTANTIAL LOSS
	ADAPTER-BOOSTER	2.15	LESS CLOSURE PLUG
	ADAPTER	6.	AS GIVEN ON DRAWING
	BURSTING CHARGE	53.35	AS GIVEN ON DRAWING
	COMPLETE AS LOADED	1040.5	AS GIVEN ON DRAWING
	COMPLETE AS LOADED		PREDICTED FOR FUZE AND LOCK NUT
FIN ASSEMBLY		21.	AS GIVEN ON DRAWING
FUZE, NOSE,			
FUZE, TAIL, M102 OR M102A		3.20	AS GIVEN ON DRAWING
FIN COUPLING AND LOCK NUT		3.70	AS GIVEN ON DRAWING
COMPLETE AS DROPPED		1077.	AS GIVEN ON DRAWING
COMPLETE AS DROPPED		1077.5 ± 0.15	AS GIVEN ON DRAWING
EXPECTED MAXIMUM VARIATION IN WEIGHT AS LOADED 1.1%			
RATIO, WEIGHT OF CRISTING CHARGE: WEIGHT AS LOADED 10.03%			
EXPERIMENTAL DESIGNATION:		STANDARDIZED BY:	

PREPARED IN DAL. RES. LAB. A.P.G.

lug-bands and were filled with Explosive D. The modified bombs had their lugs screwed on the body and were filled with cast TNT. The unmodified bombs are numbered 12, 14, 16, 18, 20, 22, 24, 26, and 28. The modified bombs are numbered 11, 13, 15, 17, 19, 21, 23, 25 and 27. The modified bombs carried an experimental designation of T1.

The bomb is assembled with Fuze, Bomb, Tail, M102 (modified). This is a vane type fuze with a 0.04 to 0.06 second delay. The bomb was equipped with steel box-type fins. The percentage of bursting-charge to actual weight as dropped is 5.4 per cent. The range bombing program was authorized in correspondence.00 471.62/222.

III Preparation of Bombs

The bombs were fully loaded when received at the Proving Ground, so that it was only necessary to assemble fins and fuzes to them.

IV Mechanical Constants of Bombs

The mechanical constants of each bomb were determined before it was loaded into the airplane.¹ The detailed results of these measurements are given in Appendix A. A summary of the results for the Bomb, A.P., 1000-lb., M52 is given in the table below:

	m	\bar{x}	I_T
	Weight Complete as Dropped	Distance of Center of Gravity from Nose	Moment of Inertia about Transverse Axis through Center of Gravity
	lb.	in.	lb.ft. ²
Mean	1080.3	28.32	1566
Standard Deviation	2.30	0.15	7
Maximum	1086.0	28.82	1584
Minimum	1076.5	28.13	1552
Number of Bombs	17	17	17

¹ No moments of inertia about the longitudinal axis were obtained for these bombs.

These statistics refer to all bombs for which a ballistic coefficient with respect to any element was obtained. The actual variations in weight of these bombs do not affect their flight characteristics sufficiently to cause a variation in ballistic coefficient large enough to be detected by the methods for estimating the ballistic coefficient which were used in the reduction of field data. The variation in center of gravity position and moments of inertia would, if sufficiently in excess of that for the present bombs, affect the yaw of the bombs and thereby the dispersion in the elements range, time of flight and trail.

The positions of the centers of gravity of the bombs summarized above were measured with fins and fuzes.

V. Description of the Range Bombing

The bombs in this range bombing program were dropped from the B-18A, and the B-23 airplanes at a target anchored in Bush River in such a position that the release points were in the fields of view of the Vertical and Oblique Cameras Obscura. The direction of the approach to the release points on all runs was from southeast to northwest within 15°

On all approaches on which bombs were dropped horizontal flight was maintained as nearly as possible. In all cases except May 3, 1941, the piloting was done by means of the automatic flight control equipment. On this date the equipment did not work and the piloting was done manually.

In these airplanes the bomb racks are so arranged that the longitudinal axis of the bomb is nearly parallel to the thrust line of the airplane. Hence the initial yaw of the bomb in the vertical plane is nearly equal to the angle of attack of the airplane.

On all approaches with the B-18A airplane, the bombs were carried in the rear bank of the bomb racks. The center line of this rack is 12.8 feet to the rear of the point formed by the junction of the front edge of the wing with the fuselage of the airplane, this junction being the point on the airplane plotted in the cameras obscura. The corresponding distance in the B-23 is 12.1 feet.¹

All bombs were dropped according to the current standard practice of the Air Corps, using the current standard bomb sight and a target in Bush River as an aiming point. The results of this range bombing are shown in Appendix B. For the

¹ The effect of bomb bay release position on the estimated values of the ballistic coefficients is discussed in Ballistic Research Laboratory Report No. 136: "First Progress Report: On the Method of Reduction of Observations on the Elements of Bomb Trajectories."

purpose of this report, the displacement of the center of impact with respect to the target is of no special significance. The dispersion about the center of impact and other data summarized in Appendix B are, however, of considerable interest.

The bombs dropped were divided into groups and the endeavor was made to have the altitude and air speed within the group approximate as nearly as possible to certain specified values. These values were described as the standard altitude and the standard air speed.¹

The number of bombs in each group and the standard altitude and standard air speed for each group are given in Appendix D. The reasons for the selection of these standard altitudes and air speeds are given in Sections VI and IX of this report.

The range bombing was conducted by the following:

Pilots:

Capt. S. C. Smink, A.C.
First Lt. R. Billings, A.C.
First Lt. A.C. Perry, A.C.
First Lt. C.A. Reissaus, A.C.

Bombardiers:

Capt. M. F. Summerfelt, A.C.
Capt. S. C. Smink, A.C.

Proof Officers:

Capt. J. G. Shinkle, O.D.
Mr. C. Brown, O.D.

VI. Ground Observations

The primary ground observational equipment employed was the Camera Obscura Installation.² The position of the aircraft in space and its components of velocity were fundamental data obtained by reduction of observations made with this equipment.

¹ Compare the usage of these terms for statistical purposes in Sections VIII and IX of this report.

² A basic description of the Camera Obscura Installation is given in the "First, Second and Third Progress Reports on Bomb Trajectory Study by the Camera Obscura Method" by Frank Short, F. V. Ludden and S. P. Willan. The equipment has been extensively modified and improved during 1938 and the current equipment and its accuracy are described in Ballistic Research Laboratory Report No. 144: "First Progress Report: On the Accuracy of the Camera Obscura Installation for Obtaining the Initial Data of Bomb Ballistics."

The field data for determinations of times of flight were secured by the chronograph installation housed in the Vertical Camera Obscura. The instants of release and impact were recorded by this chronograph-hydrophone system which has been in use in the present form since 1937.¹ In addition the field data for determinations of the times of flight of 8 bombs were obtained by the Western Electric Camera Clock. The clock in the camera is started by the same radio release signal that is recorded by the chronograph-hydrophone system cited above. The camera photographs the impact of the bomb on Bush River and the clock face within the camera at the same instant. The rate of the camera at this time was approximately 200 frames per second.

The coordinates of the impacts referred to the camera coordinate system were obtained by the ground observers by means of azimuth instruments on three towers along the shore of Bush River and were furnished to the Bombing Unit of the Ballistic Research Laboratory. The ground observers also provided the dispersion data with reference to the target and the reduced meteorological data for securing corrections to the elements tabulated in the bombardier's approximate bombing tables. The latter results are graphically summarized in Appendix B, "Primary Results of Range Bombing".

The field data necessary for the reduction of the effects of non-standard meteorological conditions were obtained from two sources. The data secured by the camera observers were the coordinates on the camera plotting boards of smoke puffs at regular time intervals for a series of altitudes, to be used in obtaining ballistic winds; the velocity and the direction of the wind at the earth's surface; and the temperature, the relative humidity and the barometric pressure of the air at the earth's surface. The data secured by the Range Observation Section observers were the spatial positions of a balloon at regular time intervals, and the velocity and direction of the wind at the earth's surface. The temperature and barometric pressure at a series of altitudes were obtained from the bombing flight records of the bombardier. These data were partially reduced by the Range Observation Section and were furnished to the Bombing Unit in the form of tables of:

¹ The calibration of this system and the measurement of the systematic errors to which it is subject were carried out in 1938 and are described in Ballistic Research Laboratory Report No. 130: "On the Measurement of the Time of Flight of Bombs". The absolute accuracy and internal precision of the method in actual practice has been determined recently and the results are given in Ballistic Research Laboratory Report No. 211: "Comparison of Measures of the Time of Flight of Bombs by the Camera Obscura Chronograph and the Western Electric Clock".

- (1) The actual wind components at a series of altitudes, and
- (2) The density of the air at a series of altitudes relative to standard ordnance air density structure.

The actual wind components were taken along a fixed line of known azimuth in the bombing lane, with the sign positive when taken along the direction of flight and positive when taken to the right. The actual wind components and the densities were obtained as near to the time the bombs were dropped as was practicable.

Field data on range bombing with the Bomb, A.P. 1000-lb., M52 for the bombing tables, BT-1000-B-1, were obtained from the program carried out between April 28, 1941 and June 6, 1941. This included range bombing at 2,000, 10,000 and 25,000 foot altitudes. The advance of ballistic theory and increased accuracy of measurement during 1938 and 1939 showed that better results can be obtained from groupings at the maximum obtainable altitude of release, a central altitude and a low altitude.

Field data for both range and time of flight were obtained and trail determinations were made wherever possible. A total of 17 ranges,¹ 21 times of flight and 19 trails was obtained.

VII. Reduction of Field Data

The data secured by the ground observers at the cameras were utilized to obtain the position and velocity of the airplane at the instant of release. The data secured by the ground observers at the azimuth instruments were utilized to obtain the positions of impact of the bombs. The time intervals obtained from the chronograph strip were employed to determine the uncorrected interval between release and impact. The time intervals from the Western Electric Camera film were likewise utilized. These data were then corrected for instrumental errors.²

¹ On May 27, 1941, Run Number 1, Bomb Number 23, the short range and less than vacuum times (microphone and Western Electric) indicate the bomb left the plane approximately 1/3 second before the release signal was received. Therefore the values were not included in the group mean.

² The character of these instrumental errors is discussed in Ballistic Research Laboratory Reports No. 144, 130 and 211, previously cited.

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VIII. Determination of Ballistic Coefficient

The reduction of field data furnished values of range and time of flight corresponding to a certain set of known values of altitude and air speed, but containing the effects of departures from standard ballistic table conditions.¹ The method of reduction of field data in order to obtain ballistic coefficients with respect to range, time of flight and trail is discussed very briefly in Ballistic Research Laboratory Report No. 191.² The computation of the ballistic coefficients is carried out by means of a Bomb Ballistic Reduction Table which was prepared in the Ballistic Research Laboratory.³

In accordance with the principles remarked above the ballistic coefficients corresponding to the ranges, times of flight and trails were then deduced for each individual bomb. From these coefficients the ranges, times of flight and trails were then computed for the standard altitude and standard air speed of the group to which the bomb belonged. These are called the "standard ranges", the "standard times of flight" and the "standard trails", or in general, the "standard elements" and are given in Appendix C together with the corresponding ballistic coefficients. This appendix also lists the program, the group, the serial number stamped on the bomb, the date of release and the run number, the last two providing for comparison with Appendices A and B.

The standard elements and the ballistic coefficients corresponding thereto contain the effects of certain unknown instrumental inaccuracies and of certain departures from standard bombing table conditions which it was not feasible to remove in advance. However, the effects of these sources of dispersion were partially removed by the process used for construction of the bombing tables.

¹ Standard ballistic table conditions and standard bombing table conditions are discussed and compared in Ballistic Research Laboratory Report No. 145: "On the Theory of Motion of the Bomb".

² The method of reduction of field data in order to obtain ballistic coefficients with respect to range, time of flight and trail has undergone considerable evolution. The reports from which the present methods were developed include: Ballistic Research Laboratory File E-IV-3, "Explanations and Comparisons of the Camera Obscura Methods of Computation"; "Computation of Firing Tables for the U. S. Army"; and Ballistic Research Laboratory Report No. 136, previously cited.

³ A discussion of the ballistic coefficients corresponding to range, time of flight and trail is given in Ballistic Research Laboratory Report No. 143: "Errors in Trail Resulting from Ignoring Either the Measured Range or the Measured Time of Flight".

IX. Construction of Tables

The experimental data from which the ballistic coefficients with respect to range, time of flight and trail were determined fell into 3 altitude groups. The groups were for standard altitudes of 2,000, 10,000 and 25,000 feet. The dependence of the ballistic coefficients upon altitude of release was determined from these 3 groups.

The mean standard elements for a standard true air speed and altitude were determined for each altitude group. The mean standard element is the arithmetic mean of the individual standard elements.¹ The individual standard elements used in computing the mean standard elements had been reduced to the group standard altitude and true air speed. The use of the mean standard elements reduces the influence of the accidental errors in the individual standard elements upon the elements tabulated in the bombing table. The ballistic coefficients corresponding to these mean standard elements were then deduced. The forms of the functional dependence upon altitude of the three ballistic coefficients have been derived theoretically and verified empirically.² The lift is the cause mainly responsible for the character of the variation of the ballistic coefficients with altitude. The lift is due to the yaw arising from the initial angular velocity of the tangent to the trajectory. The effects of lift are allowed to remain in the ballistic coefficients corresponding to the mean standard elements. The functional relations referred to are:

¹ When time of flight was obtained by both the chronograph-hydrophone system and the Western Electric Camera Clock for one bomb, the average resulting is given a weight of 2 in the determination of the arithmetic mean. The average trail resulting from one measure of range and an average of the two times of flight was given a weight of 1.5.

² The derivation of the form of these relations between the ballistic coefficients and the altitudes of release is discussed in Ballistic Research Laboratory Report No. 145, previously cited.

$$C_{X_y} = \frac{C_{X_\infty}}{1 + \frac{k_X C_{X_\infty}}{\sqrt{Y}}}$$

$$C_{T_y} = \frac{C_{T_\infty}}{1 + \frac{k_T C_{T_\infty}}{\sqrt{Y}}}$$

$$C_{\lambda_y} = \frac{C_{\lambda_\infty}}{1 + \frac{k_\lambda C_{\lambda_\infty}}{\sqrt{Y}}}$$

These curves each contain two empirical quantities k and C_∞ .

The subscript ∞ refers to the mean effective ballistic coefficient for infinite altitude, and k is a parameter determining the shape of the curve.

A new procedure for estimating the values of C_{X_∞} , C_{T_∞} , C_{λ_∞} , k_X , k_T and k_λ was in use when these bombing tables were computed. The first modification consisted in changing the method of weighting the points. The earlier procedure assigned weights proportional to the product of the number of bombs in the group and a factor dependent upon a priori considerations of the probable accuracy of the determination. No account was taken of the fact that the probable error of bombing is an increasing function of the altitude of release. In consequence, unduly great weight was attached to the groups of bombs at the high altitude. The new procedure for range and trail used weights proportional to the product of the number of bombs in the group, a factor dependent upon a priori considerations of the probable accuracy of the determination and the reciprocal of altitude of release. The new procedure for the time of flight used weights proportional to the product of the number of bombs in the group, a factor dependent upon a priori considerations of the probable accuracy of the determination, the reciprocal of the altitude and the standard true air speed. The second modification consisted in a change of the functions to be minimized. The function minimized in the earlier procedure was the sum of the weighted squares of the residuals of the reciprocal ballistic coefficients. The function minimized in the new procedure was the sum of the

weighted squares of the residual differences between the mean standard elements and those elements which would result from the use of the bombing tables.¹ This modification has resulted in much smaller probable ballistic errors for bombing tables.² A considerable improvement in the accuracy of the bombing tables, has resulted therefrom. The improvement is shown by the magnitude, as compared with earlier bombing tables, of the differences between the observed mean standard ranges, times of flight and trails, and those elements which would result from employment of these tables.

The values $C_{X_{\infty}}$, $C_{T_{\infty}}$, $C_{\lambda_{\infty}}$, k_X and k_{λ} were deduced by the new procedure described above; k_T was shown to be without significance in the present instance. The values were:

$$C_{X_{\infty}} = 5.155 ; C_{T_{\infty}} = 4.282 ; C_{\lambda_{\infty}} = 3.722$$

$$k_X = -1.832 ; k_T = 0 ; k_{\lambda} = -7.848$$

The observed and fitted ballistic coefficients are compared in Tables 1, 2 and 3 of Appendix D. The relations between the fitted ballistic coefficients and the altitudes of release are shown in Plots I, II and III of Appendix D. The fitting provides for obtaining the ballistic coefficient for any altitude of release. The actual points on the plots in Appendix D are shown by dots and their probable errors by horizontal strokes placed on the sides of the dots. The computed C : Y relations are shown by heavy lines. The dotted lines furnish the probable error of forecast bands. The band is determined by addition and subtraction of the probable error of the computed C : Y relation from the curve.

The construction of the Table of DS followed general instructions given in file 00 063.2/4524 (Confidential). The trail angles, times of flight and dropping angles were obtained by interpolation with the fitted C : Y relations in the Bomb Ballistic Auxiliary Tables, computed in the Ballistic Research Laboratory. These tables give trail angles, times of flight and dropping angles as functions of the altitude of release, Y; the calibrated indicated air speed, V, or true ground speed, V_g ; and the reciprocal ballistic coefficient, $\frac{1}{C}$. The intervals

¹ The new procedure is described more completely in Ballistic Research Laboratory Report No. 136, previously cited.

² The ballistic error is a term originally used by British ballisticians to denote the difference between the bombing table range and the mean standard range for the same conditions. The ballistic error is denoted by $X-X_f$ in this report.

of the arguments used in the Bomb Ballistic Auxiliary Tables are the same as those used in the present series of abridged bombing tables. The small differences between the observed mean standard ranges, times of flight and trails, and those elements which would result from employment of these tables are shown in the columns $X-X_f$, $T-T_f$ and $\lambda-\lambda_f$ given in Tables 1, 2 and 3 of Appendix D. These differences are compared with the probable errors of the observed mean standard elements in Plots IV, V and VI of Appendix D. The importance of employment of the fitted $C_{X_y} : Y$, $C_{T_y} : Y$ and $C_{\lambda_y} : Y$ curves is shown by the small magnitude of these differences.

The range of arguments included in these bombing tables, BT-1000-B-1, is indicated in the table below:

Element	Speed mi./hr.		Altitude ft.	
	Mini- mum	Maxi- mum	Mini- mum	Maxi- mum
Trail Angle (Calibrated Indicated Air Speed)	100	250	1800	35000
DS (Calibrated Indicated Air Speed)		160	1200	36000
Time of Flight (Calibrated Indicated Air Speed)		160	1000	35000
Dropping Angle (Ground Speed)	100	250	100	10000

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Appendix A
Mechanical Constants of Bombs

Appendix A

Mechanical Constants of Bombs¹

Program Group Serial Number	Date of Release Run Number	m Weight Complete as Dropped lb.	\bar{x} Distance of Center of Gravity from Nose in.	I_T Moment of Inertia about Transverse Axis through Center of Gravity lb.ft. ²
-11	4/28/41-1	1080.5	28.35	1566
-12	2	1082.5	28.21	1579
-15	4/29/41-1	1080.0	28.31	1565
-14	2	1080.0	28.27	1561
-13	3	1077.5	28.45	1568
-16	5/3/41-1	1079.5	28.22	1562
-17	2	1079.5	28.82	1570
-18	1	1086.0	28.31	1571
-19	2	1078.5	28.32	1559
-20	5/26/41-1	1076.5	28.13	1552
-21	2	1081.0	28.44	1572
-22	3	1077.5	28.32	1572
-23	5/27/41-1	1080.5	28.21	1564
-24	6/3/41--1	1084.0	28.27	1558
-25	1	1079.5	28.17	1584
-26	2	1082.0	28.28	1566
-27	6/6/41--1	1080.0	28.44	1565

¹ The moments of inertia about the longitudinal axis were not obtained for these bombs because there is no nose fuze hole for the adapter. Interference of the fins plus the fact of the bombs being H.E. loaded made suspension from the tail impractical.

Appendix B

Primary Results of Range Bombing

RESULTS OF RANGE BOMBING NO. 148

APRIL 28, 1941

1000 LB A.P. BOMB TI

AIRPLANE B-23

PILOT: W O. S.C. SMINK

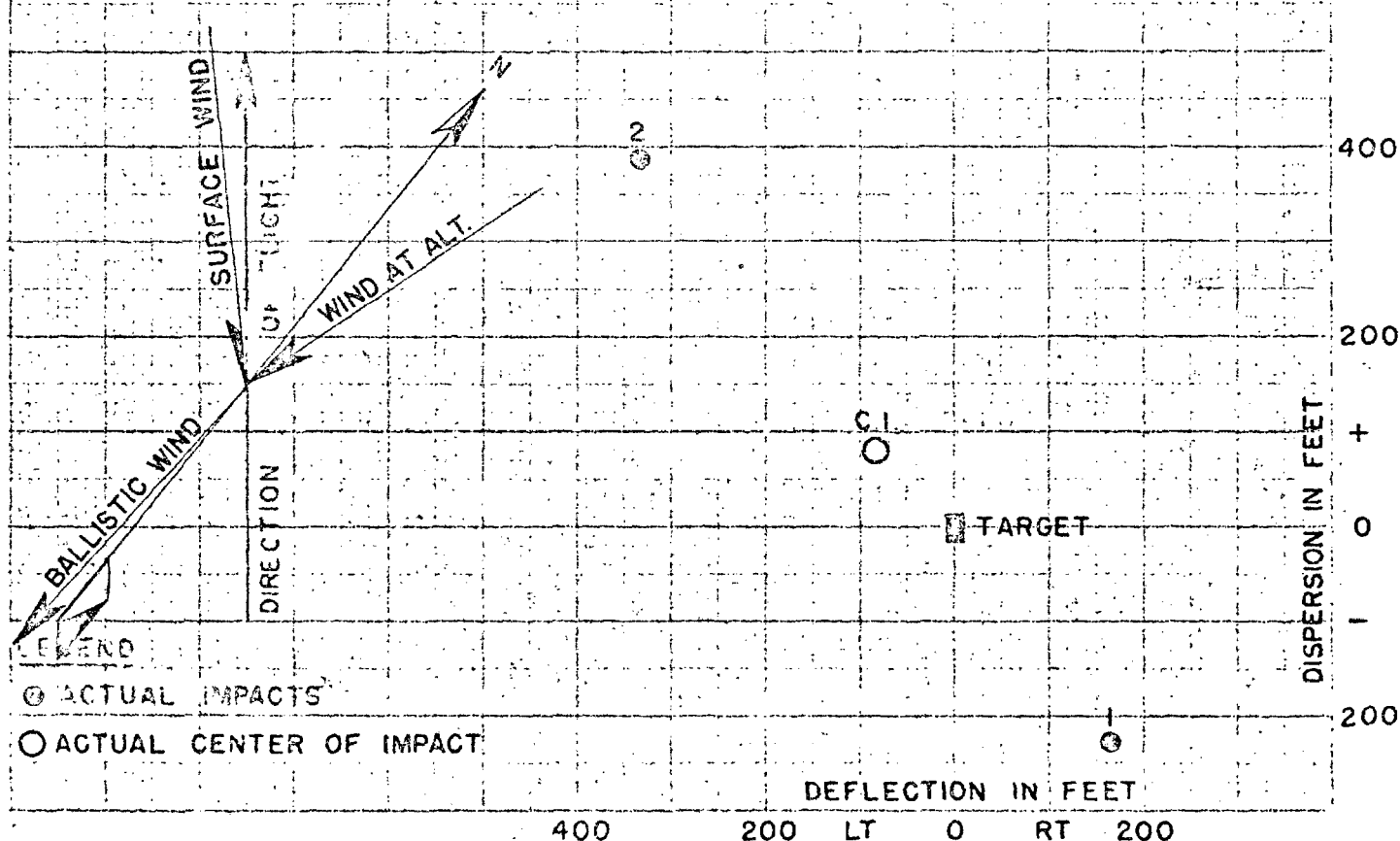
BOMBARDIER: CAPT. M.F. SUMMERFELT

SKY: SCTTRD CLOUDS AIR: HAZY-SMOOTH TRAIL AND D.S. BASED ON BT-2000 - B-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR	GR'ND	CAL IND	TRUE					GR'ND OBS.	GR'ND OBS.	RANGE	
		OBS FT.	OBS FT.		M/HR	AIR OBS. M/HR	GR'ND OBS. M/HR	GR'ND OBS. FT/MIN	FT.			FT.	RIGHT FT.
1	9:37	25465	25277	146	217.6	212.0	196.8	-24.6	10945		228	165	
2	9:48	25465	25224	146	217.4	212.3	198.0	-85.2	11201	387			333
3													
4													
5													
6													
CENTER OF IMPACT										80			84
MEAN DEVIATION										308		249	

	TIME	R.O.S.		CAMERA
		9:27		9:56
WIND VELOCITY M.P.H.	SURFACE	15.0		12.0
	AT ALTITUDE	24.8		26.5
	BALLISTIC RANGE WIND	-22.4		-20.4
	BALLISTIC CROSS WIND	-20.1		-19.8
DENSITY	AT SURFACE	1.0031		1.006
	BALLISTIC (SURFACE)	1.012		1.013
	BALLISTIC (AIR OBS.)	1.021		

NOTE: 5 MILS ADDED TO TRAIL



RESULTS OF RANGE BOMBING NO. 149

APRIL 29, 1941

1000 LB A.P. BOMB TI

AIRPLANE B-23

PILOT: LT. R. BILLINGS

BOMBARDIER: CAPT. M.F. SUMMERFELT

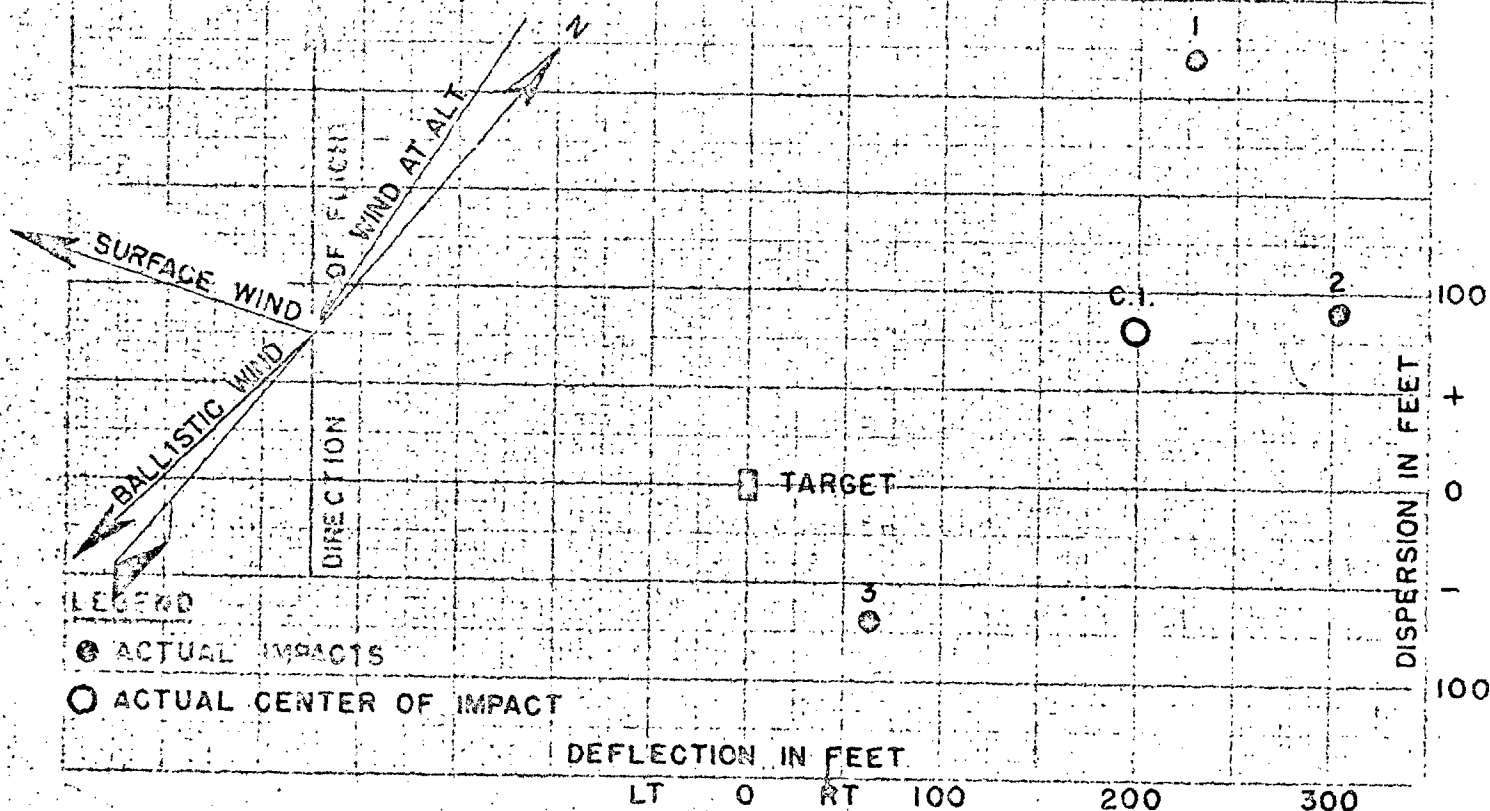
SKY: HAZY

AIR: SMOOTH

TRAIL AND DS BASED ON BT-2000 - B-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR OBS	GR'ND OBS	CAL IND	TRUE					GR'ND OBS	GR'ND OBS	RANGE	
		FT.	FT.	M/HR	AIR OBS	GR'ND OBS	M/HR	M/HR	FT/MIN			FT.	FT.
1	10:03	10500	10317	155	182.4	173.9	168.6	+77.5	6148	219		228	
2	10:15	10500	10223	170	199.8	190.1	184.0	-131.3	6673	90		303	
3	10:29	10500	10251	170	199.9	181.8	176.6	+25.8	6440		69	63	
4													
5													
6													
CENTER OF IMPACT										80		198	
MEAN DEVIATION										99		90	

		TIME	R.O.S.	R.O.S.	CAMERA
			9:20	10:40	10:15
WIND VELOCITY M.P.H.	SURFACE		5.0	7.0	3.5
	AT ALTITUDE		13.3	13.7	9.5
	BALLISTIC RANGE WIND		-9.5		-9.9
	BALLISTIC CROSS WIND		-9.8		-9.9
DENSITY	AT SURFACE		1.011	1.000	1.000
	BALLISTIC (SURFACE)		1.014	1.007	1.007
	BALLISTIC (AIR OBS.)		1.026		



RESULTS OF RANGE BOMBING NO. 151

MAY 3, 1941

1000 LB A.P. TI BOMB

AIRPLANE B-23

PILOT: LT. R. BILLINGS

BOMBARDIER: W.O. S.C. SMINK

SKY: CLEAR

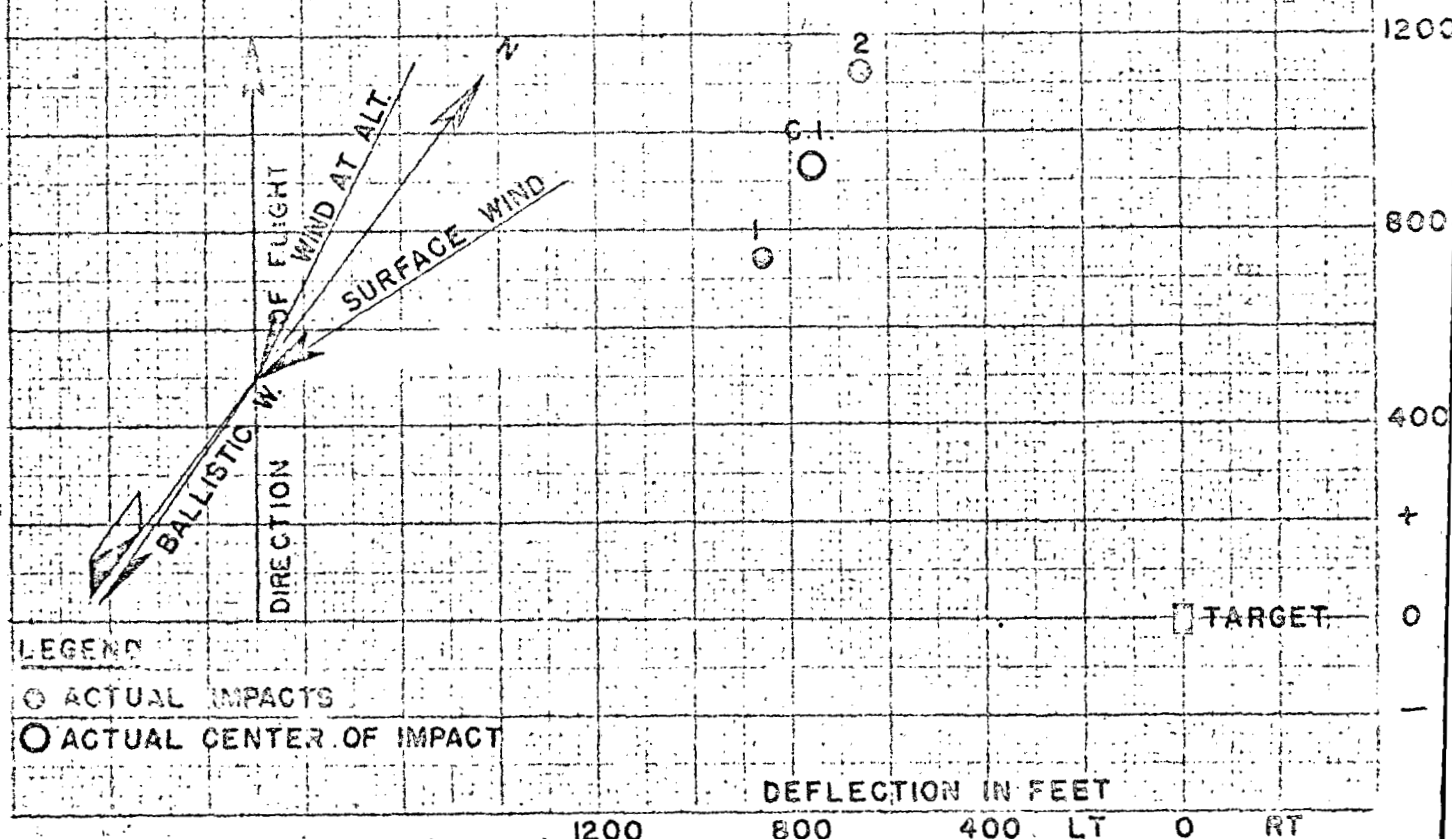
AIR: SMOOTH

TRAIL AND D.S. BASED ON BT-2000-B-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET					
		AIR OBS FT.	GR'ND OBS FT.	CAL IND M/HR	TRUE					GR'ND OBS M/HR	GR'ND OBS FT/MIN	RANGE		DEFLECTION	
					AIR OBS M/HR	GR'ND OBS M/HR						OVER FT.	SHORT FT.	RIGHT FT.	LEFT FT.
1	10:30	25150	24991	145	215.2	213.5	156.3	+75.4	8712	741			858		
2	10:30	25150	25000	145	215.2	213.4	156.2	+120.0	8725	1122			654		
3															
4															
5															
6															
CENTER OF IMPACT										932			756		
MEAN DEVIATION										191			102		

	TIME	WIND VELOCITY M.P.H.	DENSITY	R.O.S.	R.O.S.	CAMERA
				10:26		10:38
		SURFACE		11.0		18.0
		AT ALTITUDE		62.0		63.9
		BALLISTIC RANGE WIND		-36.8		-43.5
		BALLISTIC CROSS WIND		-25.9		-25.6
		AT SURFACE		1.029		1.029
		BALLISTIC (SURFACE)		1.020		1.020
		BALLISTIC (AIR OBS.)		1.015		

NOTE: BOMBS RELEASED ON SAME RUN 1.57 SECONDS APART



RESULTS OF RANGE BOMBING NO. 152

MAY 3, 1941

1000 LB A.P. BOMB T1

AIRPLANE B-23

PILOT: LT. A.C. PERRY

BOMBARDIER: CAPT. M.F. SUMMERFELT

SKY: CLEAR

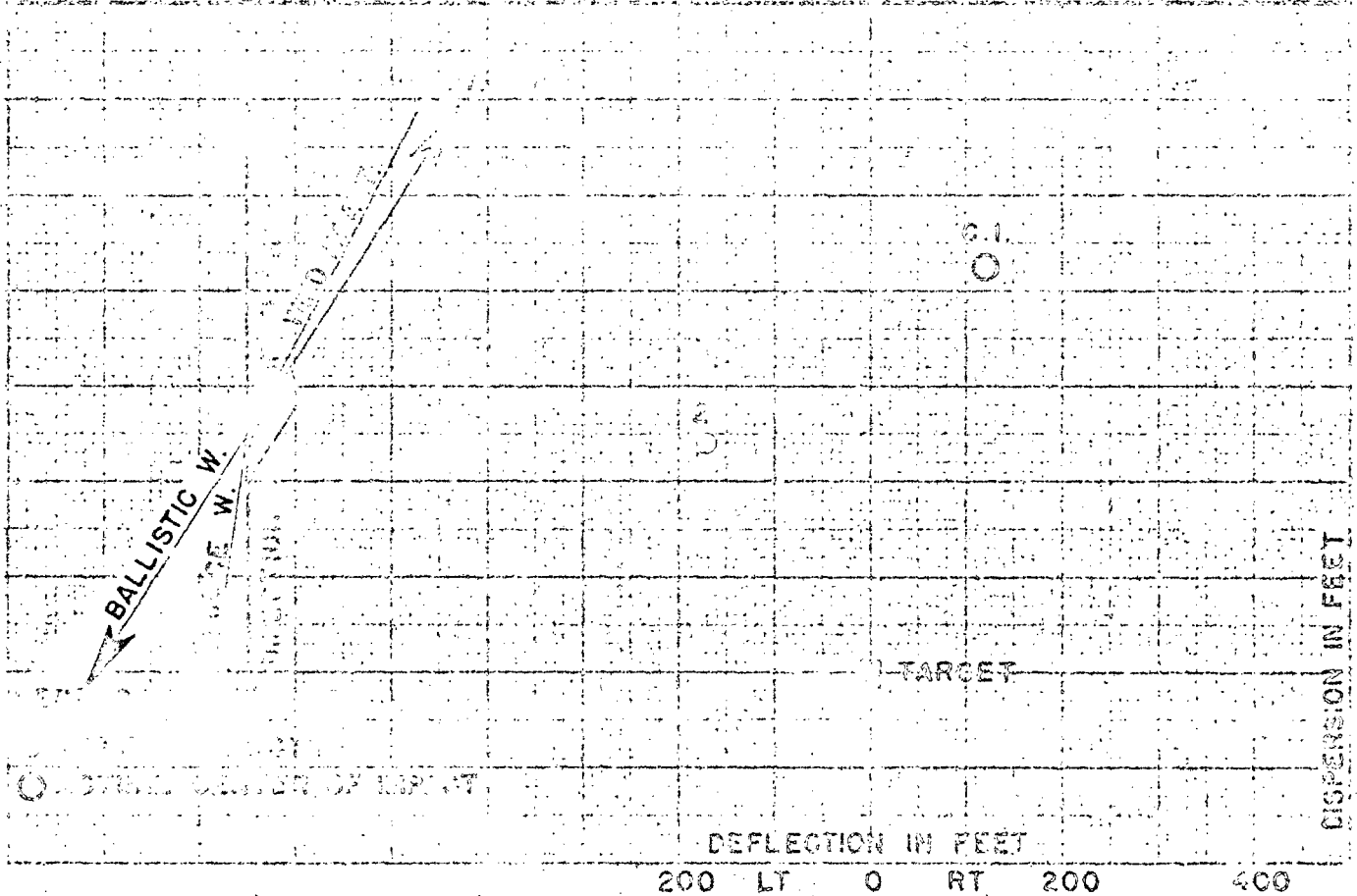
AIR: SMOOTH

TRAIL AND D.S. BASED ON BT-2000-B-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GRND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR	GRND	CAL	TRUE					RANGE		DEFLECTION	
		033	095	IND	AIR	GRND	GRND	GRND	GRND	OVER	SHORT	RIGHT	LEFT
		FT.	FT.	W/H	OBS. W/H	OBS. W/H	OBS. W/H	OBS. W/H	FT.	FT.	FT.	FT.	
1	3:40	23500	23161	120	178.5	170.0	114.6	+730	6418	609		411	
2	3:50	26135	24970	105	155.8	159.3	105.6	-126.7	5790	240			171
3													
4													
5													
6													

1	3:40	2320	2318	120	178.5	170.0	114.6	+73.0	5418	609		411	
2	3:50	23155	24970	105	153.8	159.3	105.6	-126.7	5790	240			171
3													
4													
5													
6													

CENTER OF IMPACT										425		120	
MEAN DEVIATION										155		291	
										R.M.S.	R.M.S.	OVERALL	
										3.33		3.50	
										3.3		3.3	
										39.0		43.5	
										-34.0		-35.5	
										-22.1		-22.3	
										1.017		1.037	
										1.016		1.036	
										1.015		1.035	



RESULTS OF RANGE BOMBING NO. 157

MAY 26, 1941

1000 LB. A.P. BOMB TI

AIRPLANE B-23

PILOT : LT. A. C. PERRY

BOMBARDIER : CAPT. S. C. SMINK .

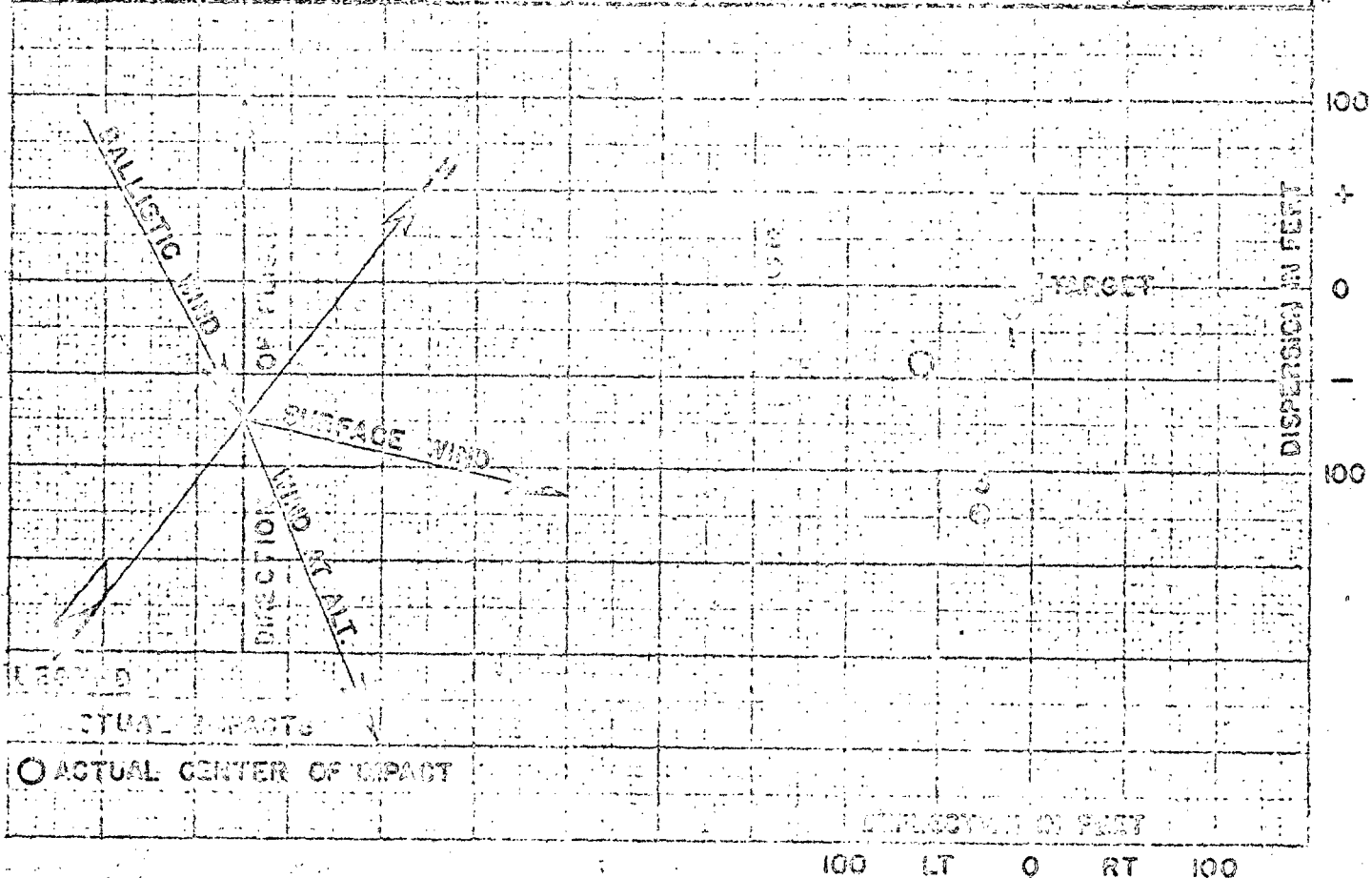
SKY : HAZY

AIR : DISTURBED

TRAIL AND U.S. BASED ON BT-2000-8-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GRND SPEED	CLIMB GR CLIMB	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR OBS	GRND OBS	CAL IND	TRUE					GRND OBS	GRND OBS	RANGE	
		FT.	FT.	M/HR	AIR OBS	GRND OBS	M/HR	M/HR	FT.			OVER	SHORT
1	3:11	10500	10435	140	165.1	157.2	110.7	125.3	3977		12		12
2	3:24	10510	10441	144	169.8	162.1	116.9	-32.2	4244	9			141
3	3:31	10510	10471	150	177.0	168.7	123.1	-26.8	4434		123		27
4													
5													
6													
CENTER OF IMPACT											42		60
MEAN DEVIATION											54		54

		R.O.S.	K.O.S.	CAMERA
	TIME	3:17		3:37
WIND VELOCITY M.P.H.	DIR. WIND	11.0		17.0
	AT ALTITUDE	48.3		52.6
	BALLISTIC CORRECTION	-39.7		-39.4
	BALLISTIC CORRECTION	20.9		21.7
DENSITY	AT ALTITUDE	969		973
	BALLISTIC CORRECTION	987		989
	BALLISTIC CORRECTION	994		



RESULTS OF RANGE BOMBING NO. 158

MAY 27, 1941

1000 LB. A.P. BOMB T1

AIRPLANE B-13A

PILOT: LT. C.A. REISSAUS

BOMBARDIER: CAPT. M.F. SUMMERFELT

SKY: CLEAR

WIND: —

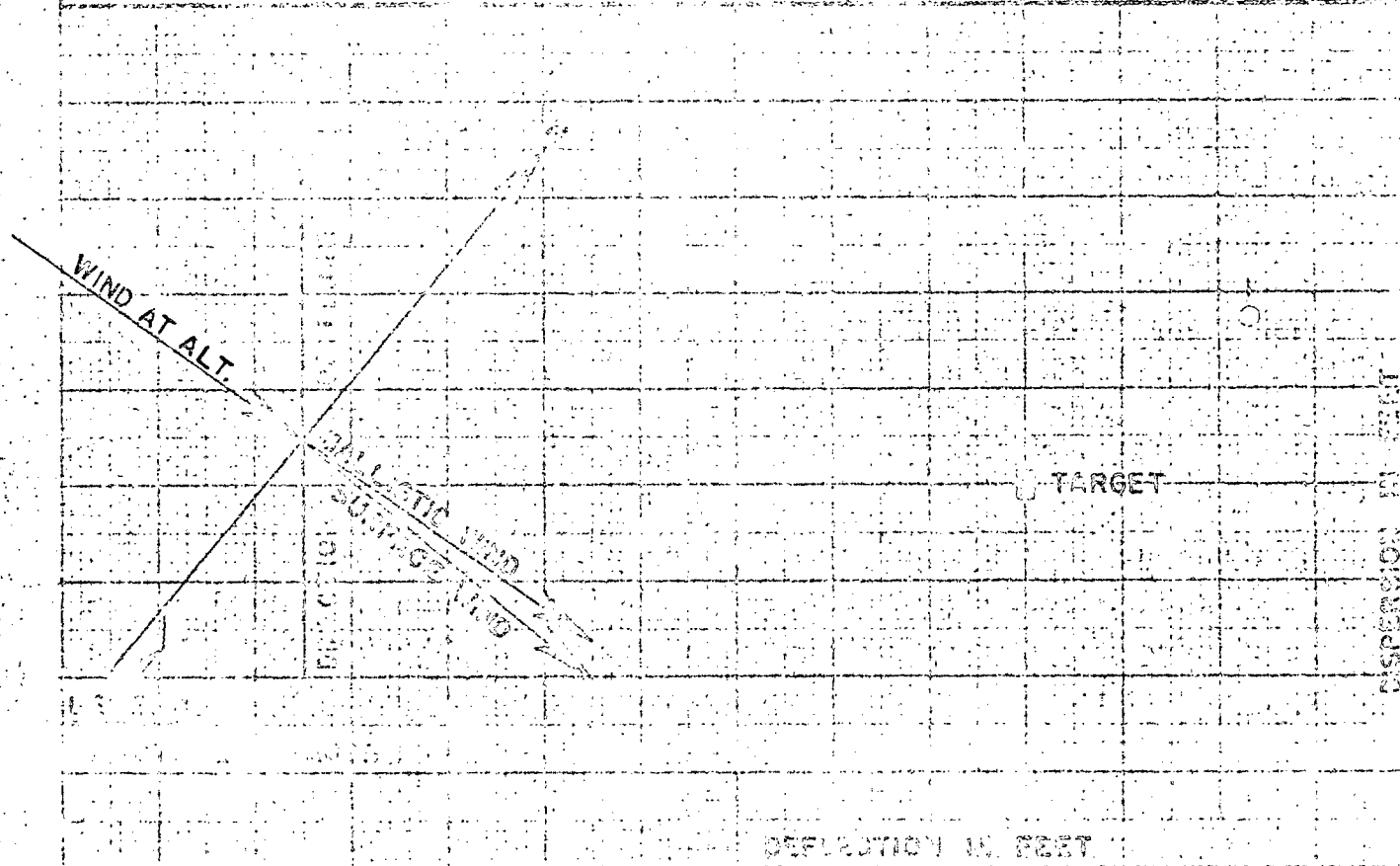
TRAIN AND O.S. BASED ON BT-2000-B-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED		GRND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR OBS	GRND OBS	CAL IND	TRUE				RANGE		DEFLECTION	
		FT.	FT.	MHR	AIR OBS. MHR	GRND OBS. MHR	GRND OBS. MHR	FT.	OVER FT.	SHORT FT.	RIGHT FT.	LEFT FT.
1	9:37	2220	2165	143	148.0	135.3	117.5	169.1	1927	87		117
2												
3												
4												
5												
6												

CENTER OF IMPACT

MEAN DEVIATION

	O.S.	A.O.S.	CAMERA
	9:50	10:30	9:52
		19.0	12.0
		27.4	21.1
		-13.6	-13.0
		21.9	17.7
		964	965
		960	970



DEFLECTION IN FEET

100 LT 0 RT 100

RESULTS OF RANGE BOMBING NO. 170

JUNE 3, 1941

1000 LB. A.P. BOMB T1

AIRPLANE B-18A

PILOT LT. R. BILLINGS

BOMBARDIER CAPT. S.G. SMINK

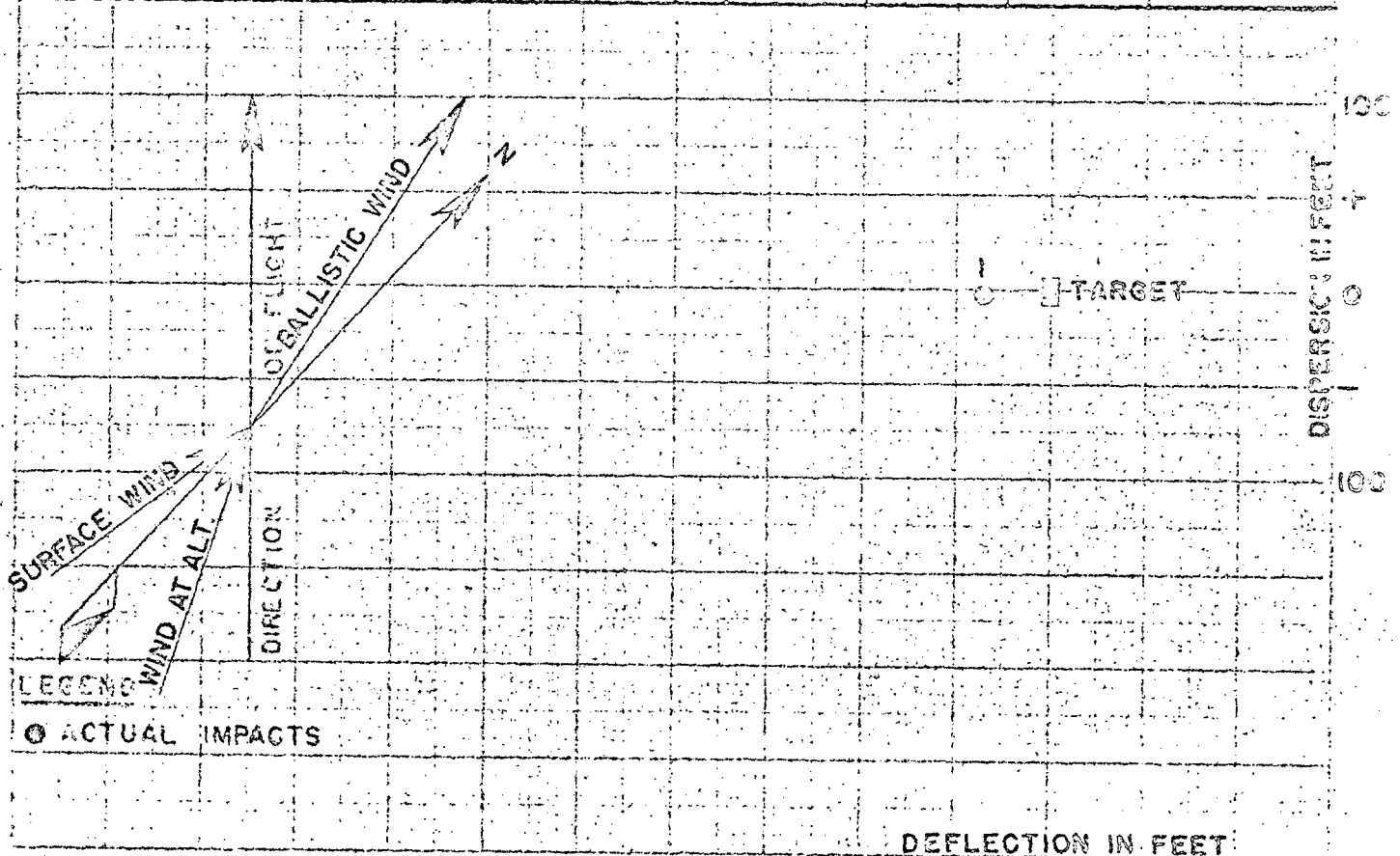
SKY : CLOUDS

AIR : DISTURBED

TRAIL AND D.S. BASED ON BT-2000-B-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET				
		AIR OBS	GR'ND OBS	CAL IND	TRUE					RANGE		DEFLECTION		
		FT.	FT.	M/HR	AIR OBS	GR'ND OBS	GR'ND OBS	GR'ND OBS	GR'ND OBS	FT.	OVER	SHORT	RIGHT	LEFT
		FT.	FT.	M/HR	M/HR	M/HR	M/HR	FT/MIN	FT.	FT.	FT.	FT.	FT.	FT.
1	11:16	2110	2079	148	152.9	157.4	164.7	-5.2	2753		3		36	
2														
3														
4														
5														
6														
CENTER OF IMPACT														
MEAN DEVIATION														

	TIME	WIND VELOCITY M.P.H.	DENSITY	R.O.S.	R.O.S.	CAMERA
				10:51	11:18	11:20
		SURFACE		2.0	2.0	4.0
		AT ALTITUDE		11.2	7.9	7.1
		BALLISTIC RANGE WIND		5.6		6.4
		BALLISTIC CROSS WIND		3.6		0.0
		AT SURFACE		.994	.994	.988
		BALLISTIC (SURFACE)		.997	.997	.991
		BALLISTIC (AIR OBS)		1.010		



RESULTS OF RANGE BOMBING NO. 171

JUNE 3, 1941

1000 LB A.P. BOMB T1

AIRPLANE B-18A

PILOT: LT. A.C. PERRY

BOMBARDIER: CAPT. M.F. SUMMERFELT

SKY

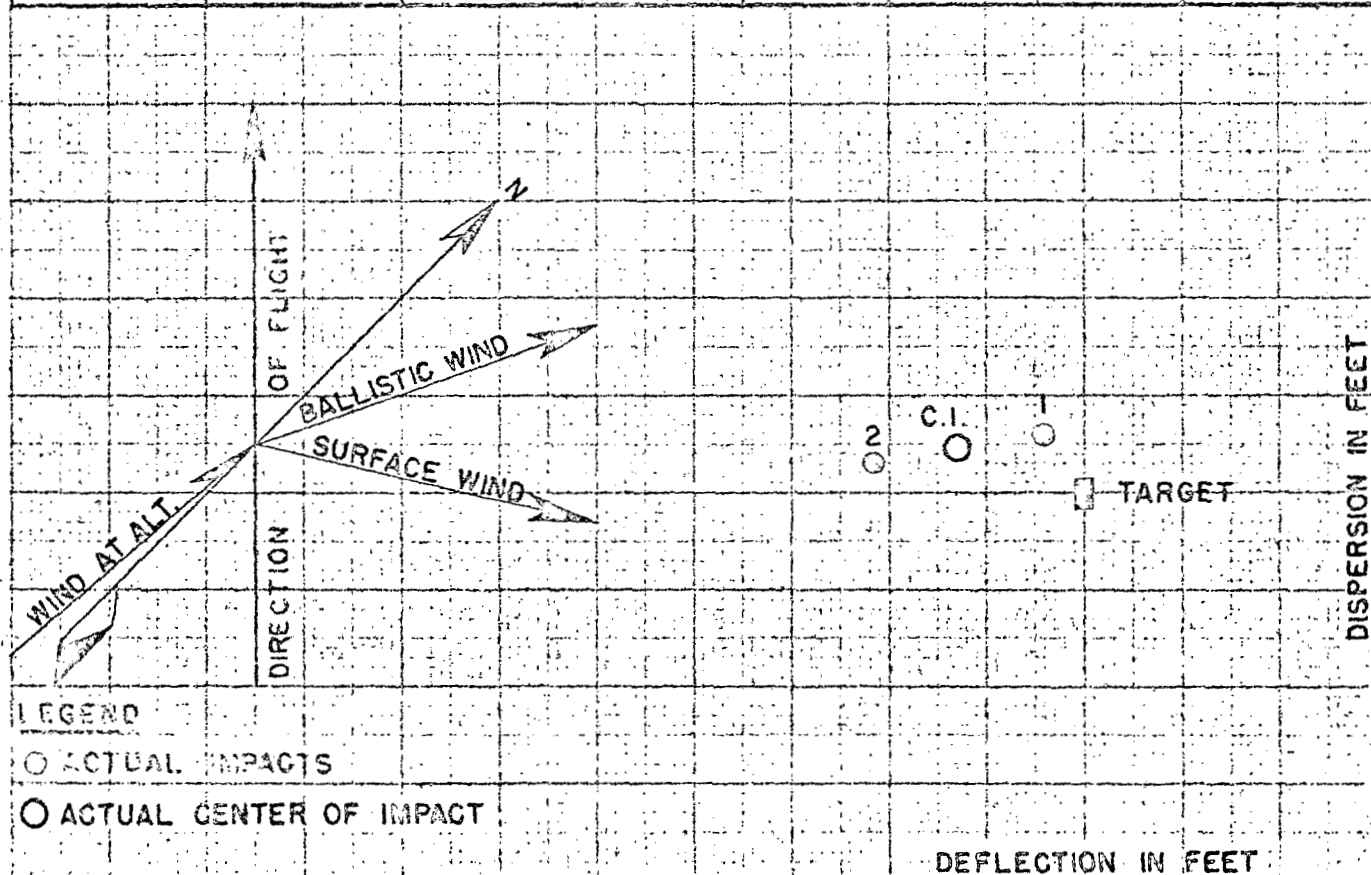
AIR: SMOOTH

TRAIL AND D.S. BASED ON BT-2000-B-1

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR OSS FT.	GR'ND OBS FT.	CAL IND M/HR	TRUE					GR'ND OBS. M/HR	GR'ND OBS. FT/MIN	RANGE	
					AIR OSS M/HR	GR'ND OSS. M/HR	OVER FT.	SHORT FT.	RIGHT FT.			LEFT FT.	
1	2:31	2040	2051	152	157.0	161.4	164.2	-82.1	2715	30			21
2	2:40	2080	2077	152	157.1	163.2	166.5	-47.2	2765	15			108
3													
4													
5													
6													

CENTER OF IMPACT										23			65
MEAN DEVIATION										8			44

	TIME	WIND VELOCITY M.P.H.	DENSITY	R.O.S.	R.O.S.	CAMERA
				2:28	3:07	2:44
				5.0	6.0	6.0
				4.0	5.2	10.4
					1.4	6.1
					3.9	4.5
				.991	.991	.934
				.994	.994	.988
				1.002		



LEGEND
 ○ ACTUAL IMPACTS
 ○ ACTUAL CENTER OF IMPACT

DEFLECTION IN FEET

200

100

LT

0

RT

RESULTS OF RANGE BOMBING NO. 173

JUNE 6, 1941

1000 LB. A.P. BOMB TI

AIRPLANE B-18 A

PILOT: LT. A. C. PERRY

BOMBARDIER: CAPT. S. C. SMINK

SKY: VERY HAZY

AIR: SMOOTH

TRAIL AND D.S. BASED ON BT-2000-B-1

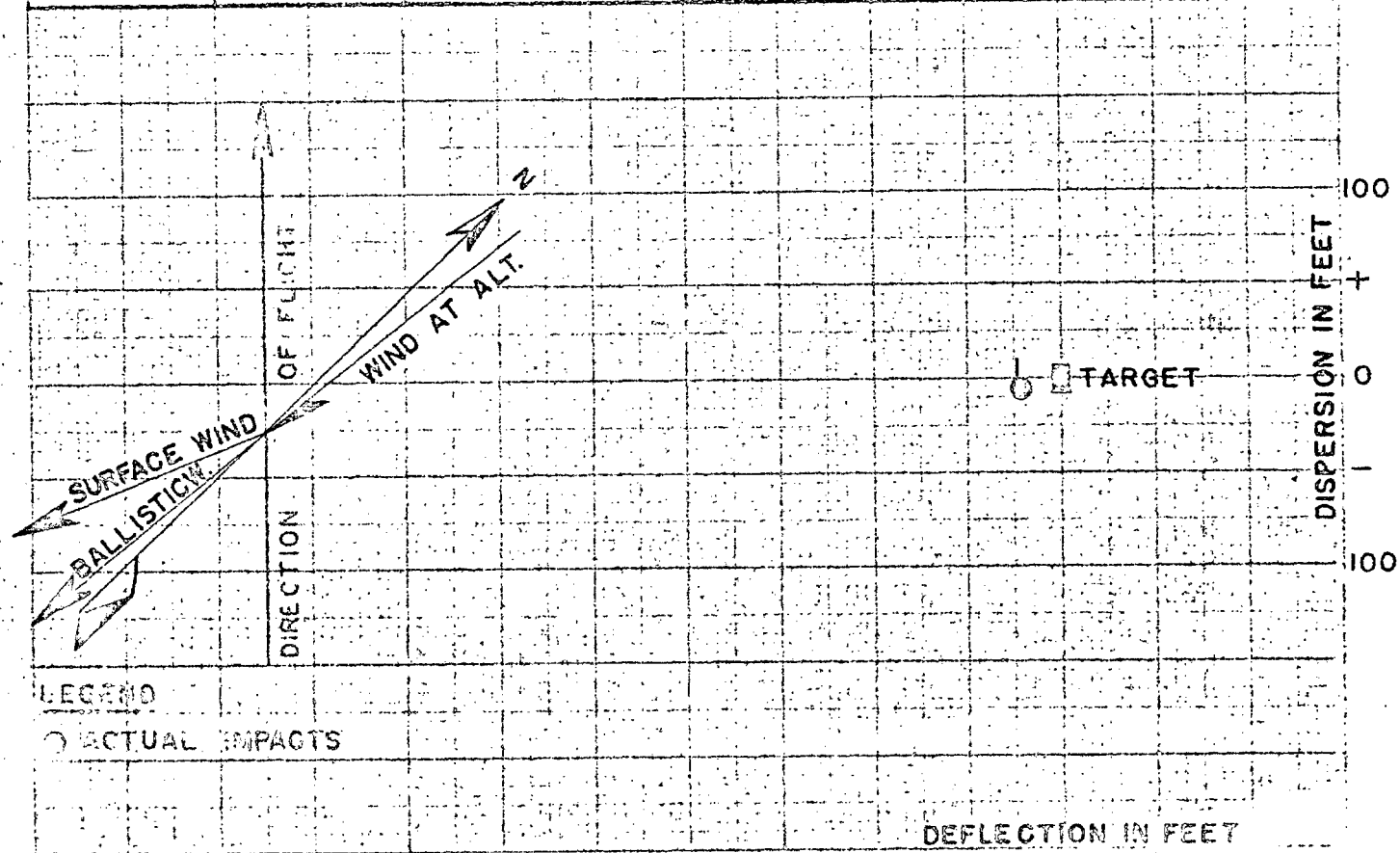
BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR OBS	GR'ND OBS	CAL IND	TRUE					GR'ND OBS.	GR'ND OBS.	RANGE	
		FT.	FT.	M/HR	AIR OBS.	GR'ND OBS.	M/HR	M/HR	FT.			OVER	SHORT
1	10:19	2130	2122	145	1499	1579	151.3	+103.4	2515		6		21
2													
3													
4													
5													
6													

1	10:19	2130	2122	145	1499	1579	151.3	+103.4	2515		6		21
2													
3													
4													
5													
6													

CENTER OF IMPACT

MEAN DEVIATION

		TIME	R.O.S.	R.O.S.	CAMERA
			10:15	11:10	10:28
WIND VELOCITY M.P.H.	SURFACE		2.0	5.0	0.0
	AT ALTITUDE		10.8	5.3	6.1
	BALLISTIC RANGE WIND		-5.0		-1.7
	BALLISTIC CROSS WIND		-6.2		-4.4
DENSITY	AT SURFACE		.991	.989	.992
	BALLISTIC (SURFACE)		.994	.992	.995
	BALLISTIC (AIR OBS.)		1.001		



Appendix C

Individual Standard Elements and Ballistic
Coefficients from Reduction of Field Data

Appendix C

Program Group Serial Number	Date of Release Run No.	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	C_X	C_T	C_λ
-11	4/28/41-1	25000	200	11185	40.92	818	4.27	4.26	4.26
-12	2			11372	WE 41.25	915		3.39	3.77
-15	4/29/41-1	10000	160	5753	41.32	748	8.53	3.24	4.68
-14	2			5775			5.46		
							7.00		
-13	3			5776	WE 25.12	119		9.94	8.00
-16	5/3/41--1	25000	200	11280	25.14	124	7.14	8.61	7.70
-17	2			11289	39.72	372	5.74	24.25	9.95
							5.92		
-18	1			11367	WE 41.85	987		2.44	3.65
-19	2			11195	41.50	808	8.32	2.91	4.41
					40.89	799	4.38	4.36	4.46
-20	5/26/41-1	10000	160	5691	WE 40.93	812		4.22	4.39
-21	2			5743	25.20	223	3.34	6.71	4.27
					25.24	179	4.96	5.90	5.06
-22	3			5705	WE 25.05	135		16.30	7.08
-23	5/27/41-1	2000	160	2510 ¹	25.34	242	3.68	4.30	3.94
					10.80 ¹				
-24	6/3/41--1	2000	160	2623	WE 10.89 ¹				
					11.18	1	-19.60	8.89	135.39
					WE 11.22	10		4.10	17.60

¹ Not included in group mean for reasons given on page 8 of text.

Appendix C (Cont'd)

Program Group Serial Number	Date of Release Run No.	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	C_X	C_T	C_λ
-25	6/3/41--1	2000	160	2623	11.18 WE 11.34	1 38	-21.14	10.44 1.48	220.02 4.61
-26	2			2613			24.33		
-27	6/6/41--1	2000	160	2572	11.16	46	2.42	91.02	3.79

Appendix D

Mean Standard Elements of Altitude Groups and Relations
Between the Ballistic Coefficients and the Altitude of Release

Appendix D
Table 1
Range

Y	U	V	N	P	X	r_X	C_X	r_{C_X}	C_{X_y}	$X-X_f$
Standard Altitude	Standard True Air Speed	Calibrated Indicated Air Speed Corre- sponding to Standard True Air Speed	Number of Bombs	Weight of Groups	Mean Standard Range	Probable Error of Mean Standard Range	Ballistic Coefficient Correspond- ing to Mean Standard Range	Probable Error of Ballistic Coefficient Correspond- ing to Mean Standard Range	Value of Ballistic Coefficient from C:Y Relation	Mean Standard Range Minus Range Corre- sponding to C_{X_y}
ft.	mi./hr.	mi./hr.			ft.	ft.				ft.
35000									5.43	
30000									5.45	
25000	200	134.8	6	1.00	11281	22.2	5.76	0.460	5.48	14
20000									5.52	
15000									5.58	
10000	160	136.6	6	1.33	5740	9.8	4.85	0.428	5.69	-16
5000									5.95	
2000	160	155.0	4	0.67	2608	8.2	11.32	9.455	6.53	7

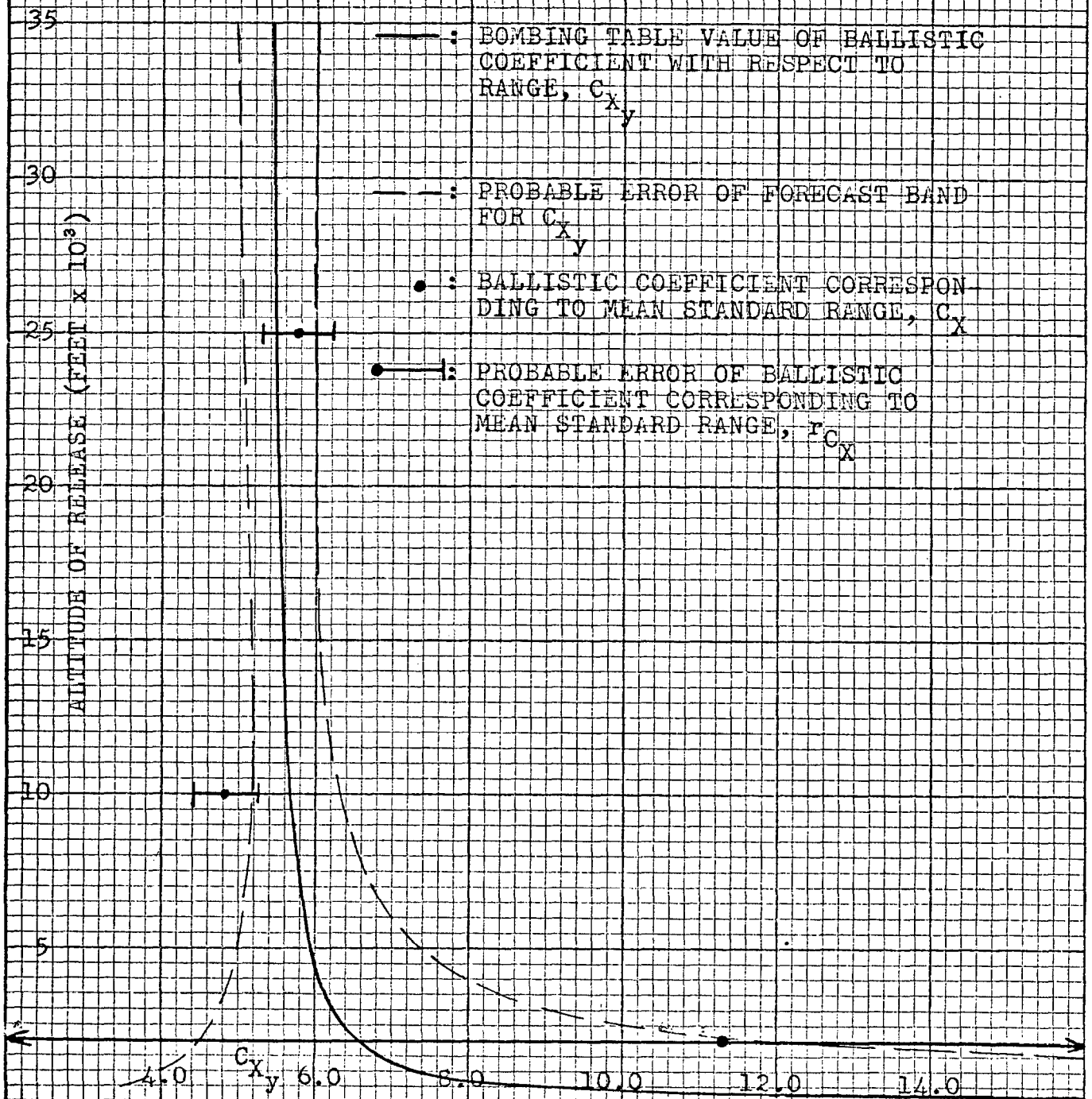
Appendix D
Table 2
Time of Flight

Y	U	V	N	P	T	r_T	C_T	r_{C_T}	C_{T_y}	$T-T_f$
Standard Altitude	Standard True Air Speed	Calibrated Indicated Air Speed Corre- sponding to Standard True Air Speed	Number of Bombs	Weight of Groups	Mean Standard Time of Flight	Probable Error of Mean Standard Time of Flight	Ballistic Coefficient Correspond- ing to Mean Standard Time of Flight	Probable Error of Ballistic Coefficient Correspond- ing to Mean Standard Time of Flight	Value of Ballistic Coefficient from C:Y Relation	Mean Standard Time of Flight Minus Time of Flight Corre- sponding to C_{T_y}
ft.	mi./hr.	mi./hr.			sec.	sec.				sec.
35000									4.28	
30000									4.28	
25000	200	134.8	6	1.00	41.05	0.150	3.87	0.409	4.28	0.12
20000									4.28	
15000									4.28	
10000	160	136.6	5	1.33	23.18	0.028	7.25	0.861	4.28	-0.17
5000									4.28	
2000	160	155.0	3	0.67	11.22	0.022	4.45	1.532	4.28	0.00

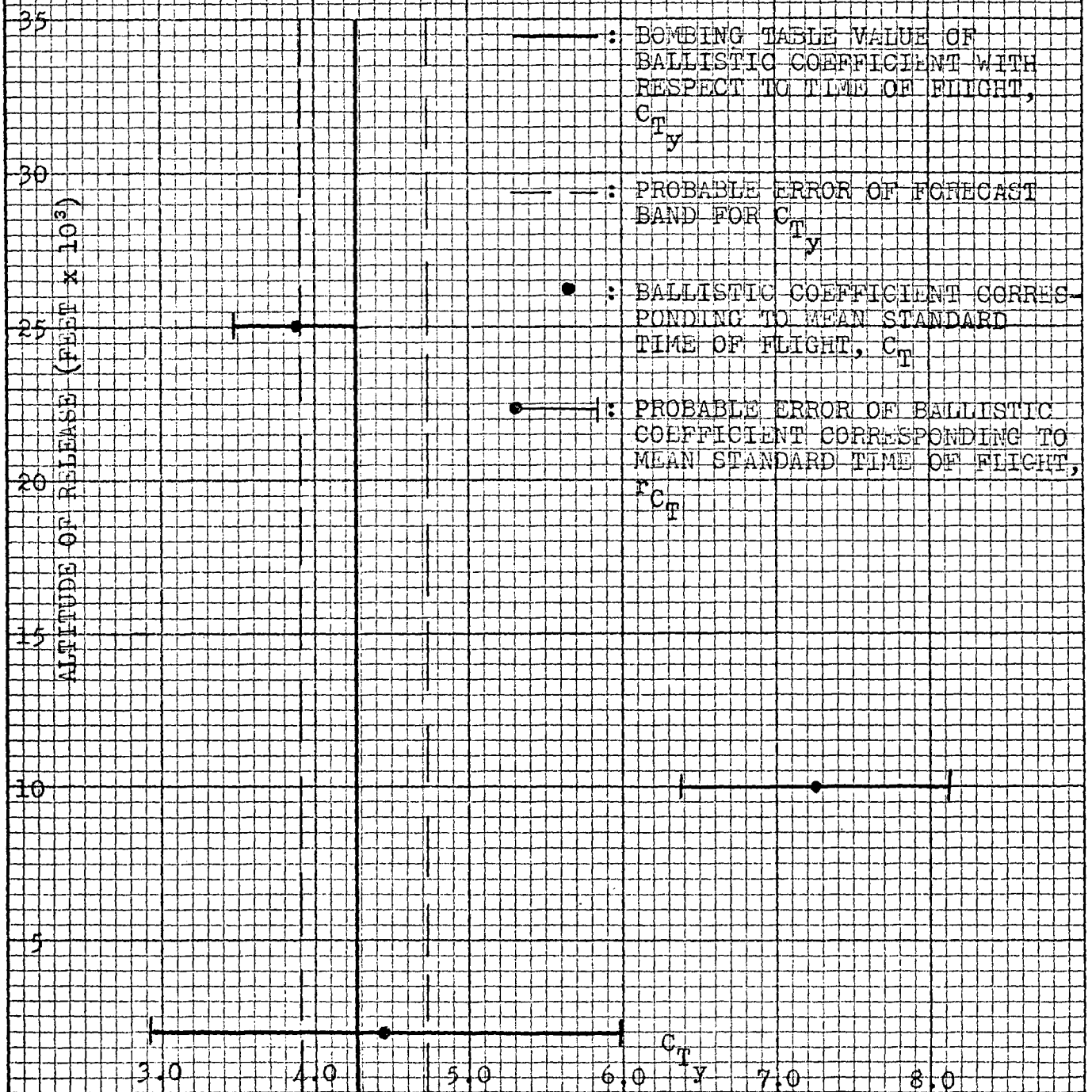
Appendix D
Table 3
Trail

Y	U	V	N	P	λ	r_{λ}	C_{λ}	$r_{C_{\lambda}}$	C_{λ_y}	$\lambda - \lambda_T$
Standard Altitude	Standard True Air Speed	Calibrated Indicated Air Speed Corre- sponding to Standard True Air Speed	Number of Bombs	Weight of Groups	Mean Standard Trail	Probable Error of Mean Standard Trail	Ballistic Coefficient Correspond- ing to Mean Standard Trail	Probable Error of Ballistic Coefficient Correspond- ing to Mean Standard Trail	Value of Ballistic Coefficient from C:Y Relation	Mean Standard Trail Minus Trail Corre- sponding to C_{λ_y}
ft.	mi./hr.	mi./hr			ft.	ft.				ft.
35000									4.41	
30000									4.48	
25000	200	134.8	6	1.00	775	49.0	4.52	0.308	4.57	7
20000									4.69	
15000									4.89	
10000	160	136.6	5	1.33	172	15.9	5.56	0.517	5.26	-10
5000									6.34	
2000	160	155.0	3	0.67	21	7.7	8.31	2.974	10.73	5

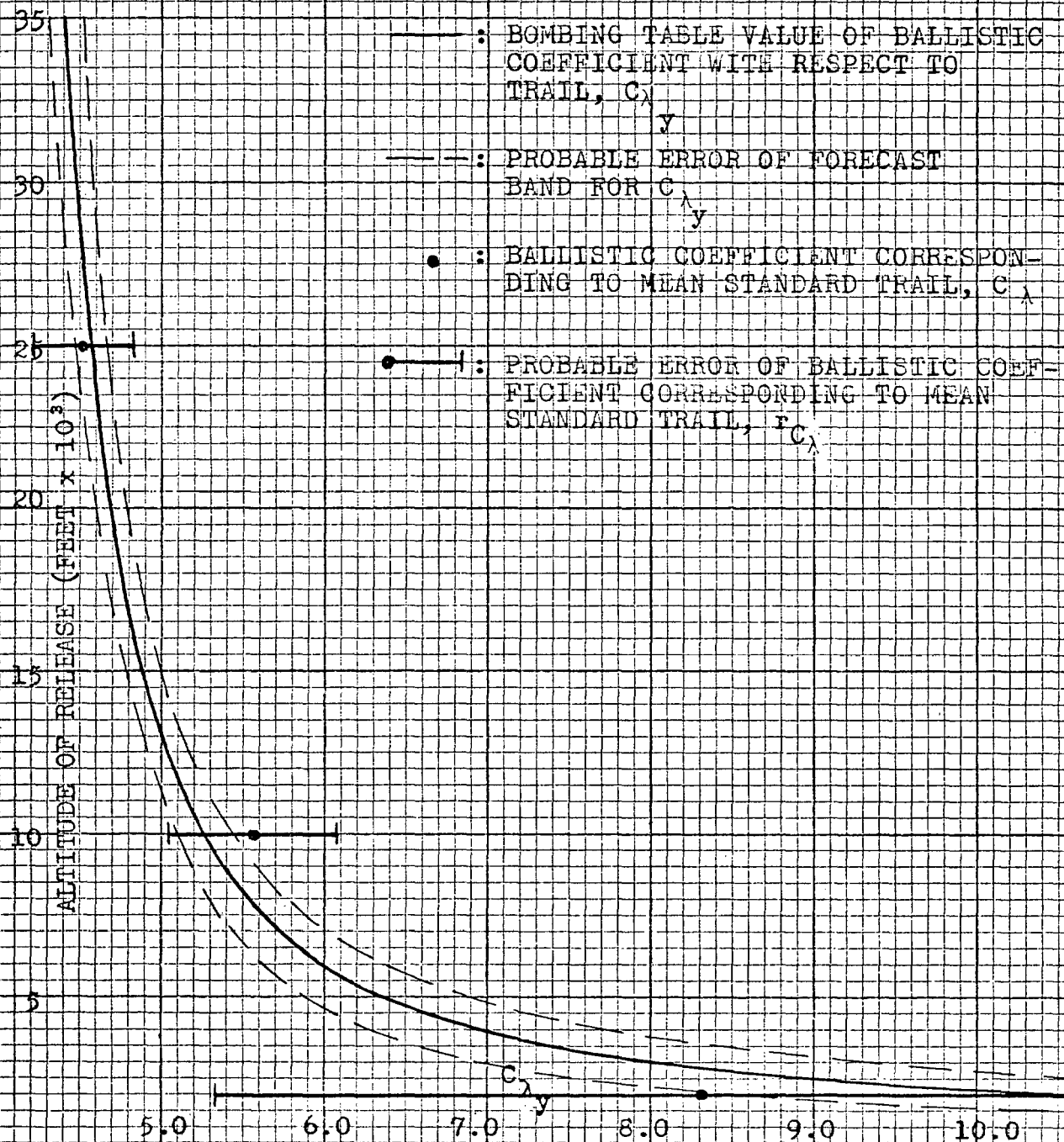
BT - 1000 - B-1
BOMB, A.P., 1000-LB., M52
PLOT 1



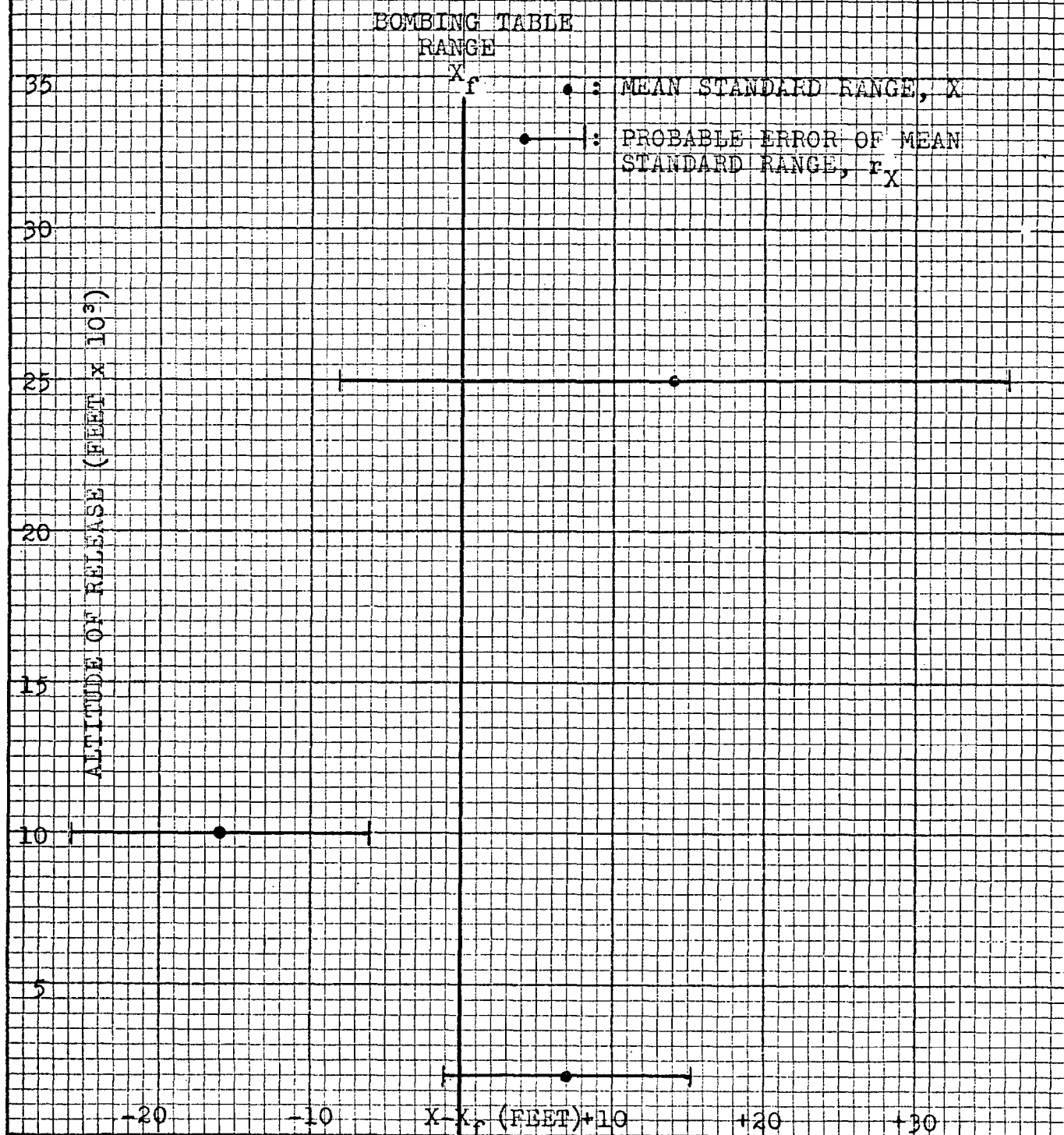
BT - 1000 - B-1
BOMB, A.P., 1000-LB., M52
PLOT II



ET - 1000 - B-1
BOMB, A.P., 1000-LB., M52
PLOT III

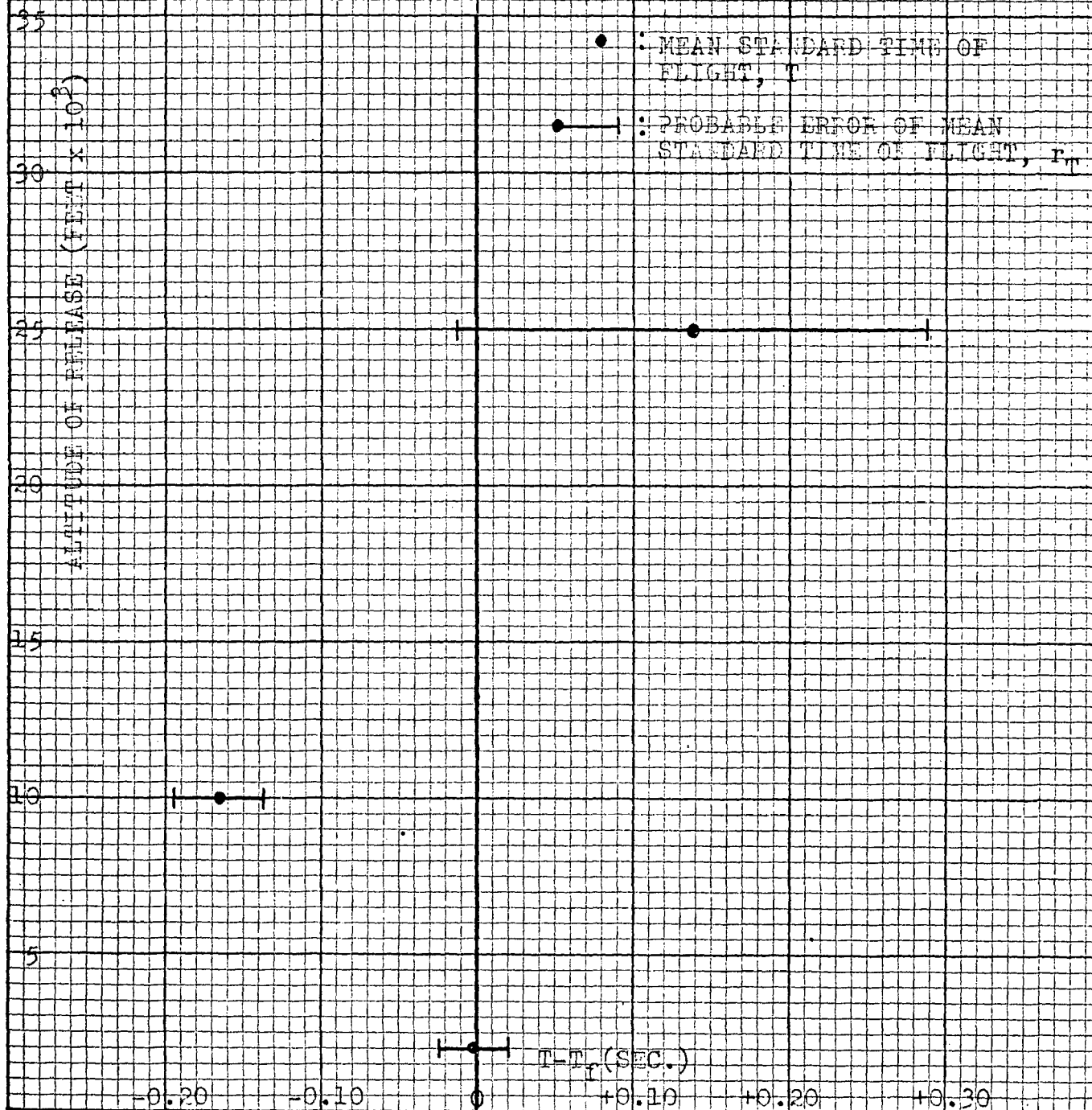


BT = 1000 - B-1
 BOMB, A.P., 1000-LB., M52
 PLOT IV



BT 1000-B-1
BOMB, A.P., 1000-LB., M52
PLOT V

BOMBING TABLE
TIME OF FLIGHT
 T_F



BT - 1000 - B-1
 BOMB, A.P., 1000-LB., M52
 PLOT VI

